Defense against small asteroids: priority tasks

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Any defense techniques (using nuclear devices or nonnuclear strategies) should be based on the knowledge of NEO'S characteristics. Investigation of NEO'S, in flight-by missions and by probing, is an important part of the planetary or regional defense programs and should be regarded as a priority task. A large number of space missions should be organized to obtain this information. To reduce cost it is preferable to use light launchers, e.g. "Rokot", and special space modules.

It is now well recognized that large asteroids (with sizes of about 1 km and more) may cause global catastrophes. Such asteroids are to be intercepted in space by heavy launchers ("Proton", "Arian", "Angara" etc.) at the distances of the order of 1 AU and months or even years before impact. Though the consequences of large impacts are grave they are rather rare. Probability of impacts of smaller asteroids (0. 3 km and less) is much higher. These small cosmic bodies are much more numerous and it is difficult to detect them. They may cause local and even regional catastrophes.

A recent impact of Comet Shoemaker-Levy 9 on Jupiter is an example of natural experimental modeling of rather small impact on the Earth's surface, as the mass of the Earth is 300 times smaller than that of Jupiter and the size is 11 times smaller. Many consequences that have been predicted for the case of the Earth (Adushkin and Nemtchinov, 1994) have been confirmed by observations of SL-9 impact, i.e. ejection of large air masses to high altitudes, fallback causing heating of the upper layers of the atmosphere due to formation of the reflected shock wave, and the subsequent infrared radiation

emission in the area which is a substantial part of the total surface of the planet (a regional catastrophe). What we have not anticipated beforehand is that the energy release would be in the form of multiple bursts due to formation of large number of fragments caused by tidal forces and that these fragments probably consist of a large number of subfragments or grains (Neukum et al. , 1995). This fact clearly shows the necessity of investigation of composition and structure of cosmic objects.

Consequences of rather small impacts on the Earth may be even more severe than is usually anticipated, if such impacts occur in industrial areas where poisonous chemical substances are produced or stored, near dams, hydroelectric and nuclear power stations, nuclear waste repositories and other vulnerable objects (Adushkin and Nemtchinov, 1994). Seismic waves may be one of the most important factors causing damage of such objects. We should underline that the regions with increased number of dangerous objects (nuclear power stations, chemical plants etc.) are usually regions with high density of populations.

Tsunami caused by the impacts into oceans and seas may also cause severe damage of the industrial areas and casualties among population living at the ocean shores (Hills and Goda, 1993; Hills et al., 1994; Nemtchinov et al., 1994). Analyzing hazards due to comets and asteroids and ways of mitigation, one should not think only about the global planetary defense systems but must also consider regional defense systems, though this idea causes a large number of problems (ethical, of international law and others). An increasing population density and a cost of human life, complexity and vulnerability of the modern human society decrease the level of damage and casualties which should be considered as not admissible.

The best way to avoid hazards due to comets and asteroid impacts (small or large) is to divert them from the Earth. Fragmentation of small objects headed into the industrial

areas or oceans may help to avoid seismic effects and tsunami, even if fragments hit the solid surface of the Earth or oceans, as such impacts cease to be coherent sources of waves. But fire ignition and even demolition by shock waves remains, if the number of such fragments and their total energy per unit area is large enough. Electromagnetic effects caused by the impacts into to the atmosphere can also be a serious problem in our information age. These effects substantially depend on the number of fragments, their masses, angle of divergence of stream of fragments and altitude of their energy release in the atmosphere, i.e. on the structure and strength of the cosmic bodies. Apparent strength of the meteoroids (determined as the stagnation pressure leading to the breakup during the atmospheric entry) is much less (usually by an order of magnitude) than the strength of meteorites (parts of meteoroids found at the Earth's surface) determined by usual tests (Svettsov et al., 1995). This fact once more underlines that it is very important to obtain real data on the structure, strength and other properties of cosmic bodies.

Any defense technique (using nuclear devices or nonnuclear strategies) should be based on the knowledge of NEO'S characteristics. Cosmic bodies may belong to various types, differently react on the action of the external force and differently behave during atmospheric entry. Not only observations of light flashes caused by rather large meteoroids (Tagliaferri et al., 1994), but investigation of NEO'S in flight - by flight-by space missions and by probing is an important part of the planetary or regional defense programs and should be regarded as a priority task. Large number of space missions should be organized to obtain necessary information. To reduce a cost it is preferable to use light launchers and special space modules. This idea is in many respects similar to that by Tedeschi and Allahdadi (1995).

One of the possible type of such light launchers is the Russian rocket "Rokot". An energy of this rocket makes

possible to launch a spaceship to the asteroid with a payload of about 350 kg. A price of such a launch is much lower than that of analogous foreign launchers. In the case of international cooperation in construction of the spaceship and instrumentation, the price may be decreased for each of the participants.

Such launches may be regarded as an attempt to test many of the aspects of the defense system against small NEO'S. We should underline that to avoid tsunami's and seismic effects the interception should be fulfilled at distances no less than about 5,000 to 50,000 km. To avoid hazards caused by the objects headed to the densely populated regions one should organize interception at distances no less than about 0.25 to 1 million km, with a warning time of about 3 to 12 days.

A very important part of the defense system is an optical-electronic space based information system, which must detect such NEO'S at distances of about 0.1 AU, supplemented by a ground based radar tracking. Even if the interception system is not ready, one can get warning from the information system and use methods of civil defense and thus decrease damage and casualties (Alimov et al., 1995). On the other hand, elements of such system may be used for detection of small NEO'S and for organization of launches to investigate them and to determine the flux of such bodies in the near - Earth space.

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